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Federal Aviation Administration  
William J. Hughes Technical Center  
Aviation Research Division  
Atlantic City International Airport  
New Jersey 08405

# **State of Charge Testing on 17 Wh Lithium-ion Cells**

August 2026

Final report



U.S. Department of Transportation  
**Federal Aviation Administration**

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| 16. Abstract<br><br>This report details the testing and analysis of intercepted UN 3480 lithium-ion cells to determine their as-delivered state of charge (SOC). Aviation regulations mandate that such cells must not exceed 30% SOC when transported as cargo to mitigate severe fire hazards.<br>In February 2025, a package containing UN 3480 lithium-ion cells was shipped by aircraft from Hong Kong to Karlsruhe, Germany. Upon arrival, the cells were observed to have previously experienced a thermal event, as the outer packaging and cells within the package had clear signs of char damage. Furthermore, the outer packaging was noted to have several puncture holes. The shipper's remaining packages were intercepted and removed from the transport network until further analysis could be conducted.<br>Representatives from the Federal Aviation Administration (FAA) Office of Hazardous Materials Safety (AXH) contacted the FAA's Fire Safety Branch to assist in the analysis. Ten packages containing lithium-ion cells from the same shipper were shipped to the William J. Hughes Technical Center, where testing was conducted to calculate the as-delivered SOC. The analysis revealed that 16 of the 18 evaluated cells significantly exceeded the 30% regulatory limit, with functional cells averaging a SOC of 60.36%. |  |                                                      |                                                                                                                                                                                                                                                                                                                                                           |                                                           |  |
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## Acronyms

| Acronym | Definition                              |
|---------|-----------------------------------------|
| A       | Amperes                                 |
| Ah      | Ampere-Hour                             |
| AXH     | FAA Office of Hazardous Material Safety |
| CC-CV   | Constant Current – Constant Voltage     |
| FAA     | Federal Aviation Administration         |
| mA      | Milliampere                             |
| mAh     | Milliampere-hour                        |
| SOC     | State of Charge                         |
| UN      | United Nations                          |
| V       | Volt                                    |
| Wh      | Watt-hour                               |

## Executive summary

Standalone lithium-ion cells – classified as UN 3480, Lithium-ion batteries *including lithium-ion polymer batteries* – are forbidden as cargo on passenger aircraft. Furthermore, they are mandated to be offered for transport at a state of charge (SOC) not exceeding 30% of their rated capacity when transported on cargo aircraft. Lithium cells and batteries with a SOC above 30% pose a significant safety risk and fire hazard to aircraft systems.

In February 2025, a shipment of UN 3480 lithium-ion cells traveling from Hong Kong to Germany experienced a thermal event, as evidenced by severe char damage and punctured outer packaging. The shipper's remaining packages were flagged, intercepted, and removed from the transport network for investigation.

Representatives from the Federal Aviation Administration (FAA) Office of Hazardous Materials Safety (AXH) contacted the agency's Fire Safety Branch to assist in analyzing the cells. Ten packages containing lithium-ion cells from the same shipper were sent to the William J. Hughes Technical Center, where testing was conducted to determine the as-delivered SOC.

Eighteen cells were selected from the delivered packages for further analysis. The cells were charged to full capacity using a constant current-constant voltage methodology and subsequently fully discharged. During this process, the specialized battery testing equipment measured the total capacity and depth of discharge, which were used to calculate the as-delivered state of charge.

The testing of the 18 sampled cells yielded the following results:

- Of the 18 cells tested, 16 significantly exceeded the 30% SOC regulatory limit for air cargo transport.
- Excluding one dead cell, the remaining 17 cells had an average as-delivered SOC of 60.36%.
- The maximum SOC among the sampled cells was 71.78%.

# 1 Introduction

Standalone lithium-ion cells – classified as UN 3480, Lithium-ion batteries *including lithium-ion polymer batteries* are strictly prohibited as cargo on passenger aircraft. When transported on cargo-only flights, domestic and international regulations require them to be at a state of charge (SOC) of 30% or less of their rated capacity (National Archives and Records Administration, 2025). Lithium cells and batteries with a SOC above 30% pose a significant safety risk and fire hazard to aircraft systems (Webster, et al., 2016).

In February 2025, a package containing UN 3480 lithium-ion cells was shipped by aircraft from Hong Kong and eventually arrived at Karlsruhe, Germany. Upon arrival, the cells were observed to have previously experienced a thermal event, as the outer packaging and cells within the package had clear signs of char damage. Furthermore, the outer packaging was noted to have several puncture holes. Other packages from the shipper were flagged, intercepted, and removed from transport until a further analysis could be conducted.

The Federal Aviation Administration (FAA) Office of Hazardous Materials Safety (AXH) enlisted the agency's Fire Safety Branch to assist with the cell analysis. Ten packages containing lithium-ion cells from the same shipper were sent to the William J. Hughes Technical Center to undergo testing and determine their as-delivered SOC.

# 2 Test setup

Upon arrival, the delivered cells were inspected. Each cell was enclosed in a hard plastic casing that displayed important charging information, including nominal voltage, maximum charge voltage, rated capacity, energy capacity, and the cell model. Figure 1 shows the cell's exterior casing.



Figure 1: Cell Exterior Case

However, other important information - such as the constant voltage termination current and discharge cut-off voltage - could not be found. Table 1 presents the charging parameters used in this study. Rows with a white background indicate values stated on the cell, whereas rows highlighted in yellow are the values that could not be found on the exterior of the case, but were either calculated or assumed based on similar lithium-ion cell chemistries.

Table 1: Charging Parameters Used

| Charging Parameter                            | Value    |
|-----------------------------------------------|----------|
| Nominal Voltage                               | 3.80 V   |
| Rated Capacity                                | 4500 mAh |
| Rated Energy Capacity                         | 17.10 Wh |
| Constant-Current Charge/Discharge Rate (0.2C) | 900 mA   |
| Max Charge Voltage                            | 4.35 V   |
| Constant-Voltage Termination Current          | 90 mA    |
| Discharge Cut-off Voltage                     | 2.75 V   |

The outer plastic casing was removed to access the battery terminals for testing and analysis. Testing was performed using two systems: a Chroma 17020 Battery Test System and an Arbin Instruments LBT 22023HC Battery Tester. The Chroma Battery System accurately measures within 0.02% of the full-scale voltage, plus 0.02% of the current voltage reading. Additionally, it also accurately measures current within 0.05% of the full-scale current range, plus 0.1% of the current amperage reading. The Arbin Instruments Battery Tester controlled voltage within 0.02% of the full-scale voltage and 0.02% of the current full-scale range.

To calculate state of charge, cells were charged to full capacity. The electric charge measured in Ampere-hours (Ah) required to charge the cells from its as-delivered SOC to full capacity was denoted as the Depth of Discharge. Once the Depth of Discharge was measured and the cell was at full capacity, it was then discharged to the discharge cut-off voltage specified in Table 1 and the electric charge in Ah was recorded as the Total Capacity. Cells were charged utilizing a constant current – constant voltage (CC-CV) charging method, typical for lithium-ion chemistries. During this process, the total charge capacity and discharge capacity (Ah) were measured and recorded by the battery test system. The as-delivered SOC was then calculated using Equation 1 below.

$$SOC = \frac{(Total\ Capacity - Depth\ of\ Discharge)}{Total\ Capacity} \quad 1$$

Based on the methodology described within this report, the discharge capacity of the fully charged cell is equivalent to the total capacity, as cells were discharged from 100% to 0% SOC.

### 3 State of charge results

Table 2 presents the SOC results for the 18 cells evaluated in this study. One of the 18 cells had no voltage. Since it was a dead cell, it was not charged and its SOC was denoted as 0.00%.

Table 2: State of Charge Results for Each Cell

| Cell # | Initial Voltage (V) | Depth of Discharge (Ah) | Total Capacity (Ah) | As-Delivered SOC [%] |
|--------|---------------------|-------------------------|---------------------|----------------------|
| 1      | 3.97                | 1.51                    | 4.50                | 66.53                |
| 2      | 3.99                | 1.39                    | 4.61                | 69.83                |
| 3      | 3.98                | 1.30                    | 4.59                | 71.78                |
| 4      | 4.01                | 1.64                    | 4.60                | 64.37                |
| 5      | 3.93                | 1.80                    | 4.54                | 60.38                |
| 6      | 3.97                | 1.40                    | 4.52                | 69.10                |
| 7      | 3.99                | 1.35                    | 4.55                | 70.21                |

| Cell # | Initial Voltage (V) | Depth of Discharge (Ah) | Total Capacity (Ah) | As-Delivered SOC [%] |
|--------|---------------------|-------------------------|---------------------|----------------------|
| 8      | 3.99                | 1.35                    | 4.58                | 70.57                |
| 9      | 3.98                | 1.39                    | 4.56                | 69.58                |
| 10     | 3.83                | 2.35                    | 4.60                | 49.07                |
| 11     | 3.89                | 1.86                    | 4.53                | 58.90                |
| 12     | 3.97                | 1.46                    | 4.72                | 69.15                |
| 13     | 3.97                | 1.44                    | 4.58                | 68.67                |
| 14     | 3.80                | 2.56                    | 4.64                | 44.73                |
| 15     | 3.97                | 1.51                    | 4.76                | 68.30                |
| 16     | 3.85                | 2.14                    | 4.61                | 53.48                |
| 17     | 3.47                | 4.77                    | 4.84                | 1.41                 |
| 18     | 0.00                | --                      | --                  | 0.00                 |

Although some charging parameters had to be assumed, any possible margin of error would be minimal. Excluding the dead cell, the remaining 17 cells which were evaluated had an average SOC of 60.36%. The highest observed SOC among the sampled cells was 71.78%. It was confirmed in the testing analysis that 16 of the lithium-ion cells tested exceeded 30% SOC.

## 4 References

National Archives and Records Administration. (2025, February 14th). Retrieved from Code of Federal Regulations: <https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-172/subpart-B/section-172.102>

Webster, H., Maloney, T., Summer, S., Dadia, D., Rehn, S., & Karp, M. (2016). *Summary of FAA Studies Related to the Hazards Produced by Lithium Cells in Thermal Runaway in Aircraft Cargo Compartments*. Federal Aviation Administration.